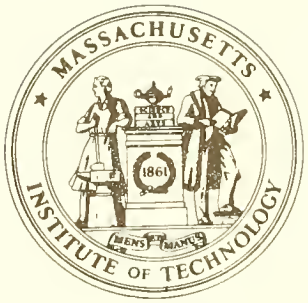

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ISSUES IN THE SPECIFICATION OF AN ECONOMETRIC MODEL OF METROPOLITAN GROWTH*

By

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Number 120 November 1973

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*This paper is part of a larger model being jointly formulated with F.M. Fisher, J. Harris, and J. Rothenberg. The author is deeply indebted to his colleagues for suggestions and guidance in this work and to Mr. Charles Pigott who has been very helpful in discussion of the formulation and estimation of this model. All errors and omissions remain of course the author's responsibility. The research was supported jointly by a Ford Foundation Grant to the Department of Economics, M.I.T. and a National Science Foundation Grant GS 37010X. The work was completed while Engle was on leave at Cornell University.

I. Introduction

It has now been ten years since John Meyer's classic survey of Regional Economics, yet many of his criticisms and suggestions remain valid. He argued for

> the formulation and testing of behavioral hypotheses with the initial emphasis being placed on hypotheses that could be quite readily developed from the application of general economic concepts already available.

The decade has seen many big regional models developed, finished or abandoned without incorporating standard economic analysis to aid in the specification of behavioral relations. Even the few tests of individual partial economic relationships are unsatisfactory because of the lack of a more general model within which to assess their implications.

This paper is an attempt to formulate an estimable model of metropolitan growth and development which incorporates standard economic theory in a consistent fashion, and which contains many of the traditional hypotheses about regional development as special cases whose validity can be tested using the data. The model is specifically designed to be a policy-model which can examine the consequences of various interventions or non-interventions by policy-makers into the process of metropolitan growth. As such, it must estimate the structural or behavioral relationships of the economy; and, while accurate forecasts are desirable, they must be of secondary importance. The endeavor in this paper is therefore to develop behavioral relations for each portion of the model and to show their grounds in economic theory.

Every model is necessarily an approximation to reality but different models make approximations in different ways. A careful examination

of the purposes of the model before the design is fixed leads to specifications which satisfy different objectives. As this is one of the first policy models of metropolitan growth, it will not be surprising if the specification is more involved than models designed merely for forecasting. A search for behavioral equations of metropolitan development leads to difficult questions of causality and theories of growth. We hope with this model not only to assist policy makers, but also to clarify the theory of metropolitan growth by providing convincing theories and quantitative estimates of the separate behavioral equations.

This model of the metropolitan region is one portion of a larger model of urban structure and development which is being constructed by F. M. Fisher, John Harris, Jerome Rothenberg, and the present author. In addition to the model of metropolitan growth which we call the Macro model to indicate the treatment of the metropolitan region as a whole, the entire model includes two additional submodels which describe the location of households and businesses respectively in the various subregions in response to the supply and demand for land with its specific features of accessibility, local government characteristics, existing stock of durable capital and price. For a fuller description of the conceptual issues in these sections see Engle et al (6). The three models are designed to be separately interesting from a policy and regional theory point of view; but together, it will be possible to consider more complex policies with more complex objectives.

The models are designed to be estimated econometrically from a time series of data from the Boston metropolitan area and its constituent geographical subregions. The choice of a specific city was made for concreteness; the structure of the model if not the parameter values themselves should be generalizable to apply to arbitrary metropolitan

areas. To underscore our belief that this is a general model, we are contemplating the estimation of some relations on the basis of cross-sectional data, and testing the validity of our specification by reestimation on another city.

Thus far the model is in an experimental stage. Most of the data for the Macro model has been collected and most of the equations to be described in this report have been estimated in approximate form. Testing and simulations have not yet been undertaken. Because of the preliminary nature of these results, they will not be presented here.

II. Metropolitan Policy

For a model to be useful to a metropolitan policy-maker it must not only be a reliable description of the appropriate behavioral relations governing metropolitan activity; but it must also include both policy tools as explicit elements of the specification, and variables which can be used by the policy-maker for evaluating the success of the policy. In this section we will examine the tools and objectives of metropolitan planners for insights into essential elements of model specification.

Who is the metropolitan policy-maker? One of the chief frustrations of urban economists has been the lack of a metropolitan political jurisdiction. Metropolitan problems are considered the province of some portions of the Federal government, a considerable segment of the state government, especially in a small state such as Massachusetts which has only one large urban area, and a major concern of the submetropolitan political jurisdictions. While each of these organs can influence the region, none has complete control and often the objectives are different. For this model, we will take the view of policy-makers at any of these levels who respond to the interests of the geographic region

as a whole. For analysis of the conflicting interests of the submetropolitan political jurisdictions, the two location sub-models are also required.

Various criteria or objective functions have been considered for the evaluation of regional policies. In principle, the welfare of the national population as a whole as well as its distribution among regions and demographic groups should be considered. It is usual in this type of model to equate welfare with income and to assume that the policy-maker wishes not only to maximize national income, but also to minimize the inequality of income among regions and among individuals within regions. Our policy-maker will therefore be sensitive to low metropolitan income or massive unemployment. To solve these problems he must choose among his policies on the basis of their effectiveness or rely upon the market for a natural resolution. A policy-model is designed specifically to aid in such decisions.

The tools available to the local and national policy-makers can be divided into short and long run instruments. In the short run, regions experience cyclical unemployment and inflation just as does the nation except that the severity and hardship are in some cases more pronounced. Various tools are available for combating this problem, from direct transfers to the unfortunate individual or industries, to general countercyclical fiscal policies on either the local or federal level.

Long run metropolitan policies may be much more important as the decline of various industries leads to perpetually depressed areas with chronic unemployment problems. Policies which either encourage the remaining population to outmigrate or attempt to attract new industry

and jobs to the region have long been discussed. Direct grants to industry through wage, price, profit, interest rate, or tax subsidies have all been used to provide incentives to attract new jobs. Indirect subsidies through the construction of urban infrastructure, job training, and land assembly projects have also been used. These are all policies to alter the migration or the elasticity of supply of the factors of production in the region. The long run effects are very difficult to identify without a complete model and there is a wide range of opinions on the effectiveness of these policies.

From this discussion of metropolitan policy we see several specific requirements for the Macro model. First, it must explain not only the level of current income, but also the rate of unemployment, inflation and the distribution of income. It must contain channels through which both national and local expenditure, tax and monetary effects can affect these local variables. Furthermore, it must describe the region sufficiently well that the determinants of the long run migration of factors can be isolated and used to evaluate the impact of various long run policies. The model must finally examine the consequences of shifts of factors upon the major objectives of the planner.

Clearly this is a very ambitious task which is made more difficult by the requirement that it be an estimable model using econometric methodology and observable data. Nevertheless, we feel that by drawing heavily on conventional economic theory, it is possible to arrive at such a complete model specification. In the next section we will examine in a simple way the economic theory behind various existing models of regional development.

III. The Intellectual Heritage of Regional Models

The influence of the Keynesian theory upon regional models has been very profound. Under the idea that a region is a small nation, which is especially open to trade, Keynesian models of aggregate demand seem fully appropriate. Klein (12) suggests a specification which takes exactly this form. The essential feature of this approach is a concentration upon the demand for the output of the region as the prime determinant of regional output and unemployment. The supplies of factors are implicitly assumed to be very elastic and the demand for products is often assumed to be price inelastic. Thus the level of output is determined by the demand for the particular products produced in the region. Since demand is felt from the residents of the region as well as from national markets the regions which happen to have developed industries with growing demand patterns turn out to be the fortunate regions.

This framework leads directly to the most venerable of all regional models, the base multiplier model. Identifying the exogenous demand with the export sector, whose output level is determined only by the level of national demand, the familiar Keynesian multiplier leads to an expansion of local service demand and therefore output. Assuming stable parameters in the demand functions, the growth of the region is determined by national demand for its exports. In an effort to improve the performance of this model and to isolate more clearly the export sectors, the intermediate good demand functions are often traced out using input-output tables. Again, it is assumed that when a good is demanded, it will be supplied.

The criticisms of these models are well known (11) (19).

For forecasting purposes the stability of the parameters and the static formulation have been questioned. The identification of autonomous sectors with export sectors and the rather arbitrary selection of export sectors lead to further doubts about the validity of the model even for this purpose. However, for a policy model, it is woefully inadequate. There is no consideration of comparative costs which presumably are the determinants of which sectors are the export sectors. With rising labor costs it is quite possible for the sectors included in the base to change and a model ignoring this could lead to grave miscalculation of the policy effects. There is no explicit consideration of the effect of new investment which is one of the primary objectives of planners. Government expenditures and tax rates have no effect on the economy. In the standard implementation, all wages are assumed to be equal and capital is not a factor of production. The theoretical structure of the model is clearly not sufficiently rich to be used as the basis for a policy-model in that it will often suggest no effect for a particular policy or will be misleading in the effects.

The other major source of economic theory from which regional models have been developed is the international trade literature. Here the focus is on the production technology, the stock of factors of production and the comparative advantage of different countries. Factor supply is usually inelastic and unemployment ignored while the price elasticities of demand for products are very important. In the small nation approximation so often employed, demand is perfectly elastic so that output is determined entirely by cost and supply considerations. Generally the models assume that all countries

produce all goods and only the relative prices, factor endowments or comparative advantage determine which is imported and which exported. Usually all goods are considered as eligible for trade, and production technologies are identical. The traditional model of this production process is the Hecksher-Ohlin model which, under the somewhat restrictive assumptions suggested above, yields very powerful results about the relationship between factor endowment, factor payments and commodity prices.

Applications of these models to regional model building have not been as widespread because of the more demanding data problems. Early attempts to identify industries with comparative advantage were comparative cost analysis (10, pp. 233-44) and industrial complex analysis (10, chapter 9) both pioneered by Walter Isard. More recent models by Borts and Stein (3) Moroney and Walker (16) and Olsen (17) are derived from the theory of international trade. Programming models such as Mennes, Tinbergen and Waardenburg (14) are generally based upon the trade model with many supplementary complexities such as transportation costs. None of these models has been fully implemented in the sense that the structural relations have been estimated from the data. Generally the procedure is to ask whether observable consequences of the trade assumptions are consistent with historical data. The results of these tests have been mixed.

The weakness of the trade models is partly that the simplest assumptions of the Hecksher-Ohlin model are too strong to be realistic in an actual economy; but more important, the models are explicitly comparative static models and are unable to adequately account for unemployment. These

defects relegate the models to the analysis of very long run shifts in resouces and incomes. It is in this context however, that they have provided only partially satisfactory explanation of the data.

To show the dilemma faced by metropolitan planners in reconciling the supply vs. demand limited forms of model specification, let us examine the New York Regional (2) model which is one of the earliest efforts. The economic forecasts were made in two separate ways. In one portion of the model, the number of jobs is projected making the assumption that the city maintains its share of various national industrial components. In another section of the model, the population is projected using standard demographic techniques. The results of the two projections which are essentially the demand and supply of factors respectively, were of course, different. In this model, the solution was to adjust the demographic projections under the assumption that the workers would be there when needed. In the Ohio River Basin Study (13) the two projections were averaged and the forecast assumptions varied to rationalize the new projections. This procedure does lead to a consideration of both the supply and the demand for factors but the adjustment procedure is far from that suggested by economic theory.

In an excellent review of seven large regional projection

models[1] by J.W. Milliman (15), only one, the Susquehanna Basin Simulation model (9) ties together the economic and demographic sectors, so that changes in one will feed back into the other. Here economic effects feedback into the demographic sectors by influencing migration, birth rates and labor force participation rates. Local employment is determined by population and export employment as in base multiplier models; however, export employment is influenced to some extent by locational costs, thus incorporating both supply and demand elements in output and employment determination. While this specification is a considerable improvement over other models, it suffers from a very weak income sector and lack of consideration of capital as a factor of production with a commensurate treatment of investment. Furthermore, because it is a simulation model, the individual relationships are not subjected to tests against the data. The only validation of such a model is a broad consistency of patterns of development with reasonable behavior of the economy. While this is a constructive lead toward the development of policy-models, its validation and specification leave much to be done.

The two most accessible time series regional econometric models are by Bell (1) for the state of Massachusetts and Glickman (8) for

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[1] These include the New York Metropolitan Region Study, the Upper Midwest Economic Study, the Ohio River Basin Study, the California Development model, the Oahu, Hawaii model, the Lehigh Basin simulation model, and the Susquehanna Basin simulation model.

for the city of Philadelphia. The models adopt similar specifications which are quite simple and are in some respects a step backwards from the Susquehanna model. In both cases exports are determined only by national GNP while local sector output is a function of local income as in the traditional base multiplier model. Employment, unemployment, wages and migration are determined with varying degrees of theoretical justification. Both models estimate investment equations, but these are standard flexible accelerator models which do not incorporate concepts of costs or profitability. Both models are, however, only intended to be forecasting models, and as such, indicate the promise of econometric methodology to regional analysis.

However, as policy models, both are completely inadequate and lead to conclusions contrary to our understanding of economic systems. Let us examine the Glickman model in more detail as it is the more recent and as it uses metropolitan data. What is the benefit to the city of encouraging new investment? While the model explains investment, it in turn enters into no other equation and there is no effect. This answer is obviously wrong but others are seen to be wrong only after careful examination of the specification. An increase in the labor force will generate an increase in unemployment and thus lower wages as expected. These lowered wages however, do not improve the competitive position of the export industries. Instead, they lead to decreased income and <u>decreased</u> output in the local sectors. The decrease in output leads to a decrease in employment and a further increase in the unemployment rate. Lower wages lead to fewer jobs rather than more. The policy-maker in this city must be bewildered about the effects of spiraling labor costs. These paradoxes result from the assumption of zero demand price elasticities, and lack of an

output supply function.

As long as increasing costs and prices do not affect the output of an industry, we should not be surprised at the contrary behavior of the model.

IV. Special Considerations in Model Formulation

In order to insure that our specification incorporates the variety and richness of behavior necessary for policy decisions, we will compile in this section a list of features which the model must include or explain. Reference is made to Boston to show the empirical content of the features, however, they should in principle be an element of a model of any city.

Labor Costs. One of the obvious features of Boston's development has been the decline of the textile and leather industries. The standard explanation for this observation is that labor costs became too high in these industries which were labor intensive; and the industries shifted to the cheap labor pools of the southeast. Thus the cost of labor must be a determinant of the level of output and new investment in Boston, yet it must have a differential effect on different industries depending on their input requirements.

The inclusion of such a variable provides a direct means for examining the policy of subsidizing industry through payment of a portion of the wage bill.

Land Costs. As land costs rise, industries may move to areas with cheap land or may adopt technologies with different input mixes. It is commonly assumed that service and office industries which use so little land relative to their capital and labor inputs have bid up the price of central city land, thus indirectly driving out the more land intensive sectors.

Durable Capital. An important variable which distinguishes a region is its stock of inherited physical capital. Although it can reasonably be assumed that financial capital flows freely from one region to another, shifts in physical capital must be substantially slower. Only through eventual depreciation or costly conversion of specific items to other uses can the capital stock be diminished. The presence of appropriate capital for a particular industry will make it more profitable for a firm to produce that good at least in the short run, than if the capital must also be newly created. These effects may be augmented by the non-measurable costs of set-up times and investment delays. New England is often assumed to suffer from having a very old and inefficient stock of capital. Thus the measure of the stock of capital must be sensitive to its productivity and age. The implications of this adjustment for quality of capital on the effectiveness of long range policies are very important since incentives to new investment will lead to an increment of capital which is more efficient than the existing stock.

Exports. The identification of the export sector is of primary importance in most regional models. The share of the output of each industry exported must, however, vary over time and the assumption that it is constant or in particular, either zero or one, seems unreasonable especially if there is any degree of industry aggregation. In any industrial category there will be some products which are consumed locally and others which are exported. As demand conditions change, the export share may shift. For example, if Boston income rises while all else remains constant, we would observe more local consumption and a decrease in the export share. Similarly, as relative prices change we would

expect the export share to shift. These are the very factors which determine the success of a region. The assumption that the shares are constant, eliminates many of the interesting phenomena in regional development. The test of whether these shares are in fact constant is one test of the validity of the base multiplier model.

Agglomoration Economies. A metropolitan region differs from many other types of regions primarily because of its dense spatial relations. The clustering of activities minimizes transportation and communication costs, lowers the costs of providing various types of infrastructure and increases the degree and variety of specialized activities which can be profitably provided locally. A firm or household considering locating in a city will in principle compare these cost savings against the increased price of land and other urban costs. Looking at the city as a whole, these appear as economies of scale. According to some studies they become exhausted in the aggregate for moderate sized cities. Even if this is correct in the aggregate (an unsettled question), it is not true of specific activities. As a city grows and diversifies, some industries, especially those which, like business services depend upon face to face contact of highly paid executives, or, like infant firms, require a broad range of specialized goods and services immediately available, or those themselves marketing a very specialized commodity which is only profitable if the market area is large, will find it increasingly profitable to locate in the city.

Short Run Fluctuations. Short run variations in unemployment are often assumed to be more severe in cities which have a high component of cyclic industries such as manufacturing durables and defense industries (7). The transmission of business cycles from the nation to its regions must be allowed via specific industry effects. The simplest model of this behavior is to assume fixed shares of national industry output. In formulating short run behavior it will be possible to test the assumption that the shares are stable over time. Recent evidence suggests that these vary widely, (4),(18),(5) yet the assumption of fixed shares is embodied in almost all regional forecasting and input-output models.

Interregional Effects. The difference between demand from the neighboring regions and national demand as a whole should be pronounced in industries producing perishables or goods which can only be traded over a short distance such as retail sales. The New England economy has an effect on the Boston economy which exceeds its role in the national economy. This is the first half of an interregional model where feedbacks from the Boston economy also reach the New England economy.

Non-Manufacturing. The future of large cities is often viewed as

depending on exports of non-manufacturing industries such as business, financial, insurance, educational and medical services. The non-manufacturing sectors must also be treated as potential exporters. The highly visible importance of these in the Boston area underscores this.

Exchange rates. A regional economy can experience exchange rate changes only through relative inflation or deflation. The model should provide a mechanism for these effects to occur in response to excess or deficient aggregate demand. This is one of the responses to balance of payments disequilibrium. Therefore the speed and effectiveness of such corrections is an important consideration in whether regional policies are necessary at all.

Factor Mobility. Although in the short run the stocks of capital and labor are approximately fixed, in the long run both will migrate in or out in response to economic conditions in this area relative to other areas. Labor will be expected to search for areas of high wages and employment and capital for industries and locations where it can earn high rates of return. In simple trade models, these adjustments lead to an equalization of incomes in different regions. However, the data (3) suggests that the direction and size of factor flowsdo not result in equalization of returns. Generally the explanations for this divergence hinge upon non-homogeneity of the regions' resources which lead to specialized regions, or merely on the dynamics of adjustment. In examining the determinants of factor migration, these alternative scenarios must be compared. Special importance attaches to the factor migration equations since it is through them that the effects of

long run policies must be evaluated.

Income Distribution. It has often been argued that there is disguised unemployment in the central cities since many jobs do not pay even subsistence wages. When considering subsidizing an industry, its wage structure must be examined for its effects upon the distribution of income.

Regional Time Series Accounts. For a clear understanding of the data and the model, it is important that a set of regional accounts consistent with the National Income and Product Accounts be developed. The estimation with time series methods requires that this be undertaken historically as well, with careful allowance for cyclic effects.

V. Description of the Macro Model.

We have set out a series of features which a structural model of a metropolitan economy must incorporate in order to be a useful policy model. In this section we shall describe the formulation we are now using for the Macro model of Boston. Specifying a model embodying these features which is estimable with measurable data is a difficult task, yet we feel that we have made a step in that direction which will be followed by even more sophisticated models. It will be convenient to divide the behavioral relations into six separate groups which describe respectively Output, Employment, Prices and Wages, Distribution of Income, Migration of Capital, and Migration of Labor.

Output.

As was seen in the review of modeling theory, the choice between demand and supply determination of output is a watershed among models. The empirical importance of both classes of explanation can be informally established for Boston in that the decline of the textile industry must be attributed in large part to cost or supply factors, while the decline in the electronics industry in 1971 is clearly a response to military and space cut-backs and is therefore attributable to a decline in demand for the products.

An eclectic approach is to take the competitive theory and let output be determined by the interaction of supply and demand. That is, both price and output levels adjust to equate supply with demand and each point of observation reflects a market equilibrium. An alternative assumption which is more difficult to implement but which may be more realistic, is to assume that each observation is either a point on the demand curve or on the supply curve, and sometimes on both. Thus The requirement for equilibrium at each point of observation would not be imposed. This procedure may be approximated by using an auxiliary measure of capacity utilization such as weekly hours worked by the capital stock (20). We have not yet tried these alternative procedures but are contemplating their use if the equilibrium assumption proves too restrictive.

The elements of output determination are therefore the demand and supply of goods and services in each of the approximately fifteen manufacturing and non-manufacturing sectors identified in the model. The total demand for output in a sector will be the sum of the demands of local economic agents, New England agents and the rest of the nation.

Measurement of the quanitities involved presents somewhat of a dilemma. In estimating production or supply functions, value added is generally employed, while for demand functions, final goods are the quantities demanded. Because of the form of the data and the structure of the model which seeks to determine output in industrial sectors, we use value added throughout. To construct measures of final demand it would be necessary to use ad hoc assumptions such as fixed coefficient relationships which do not address the very crucial question of whether intermediate goods are produced locally or are imported. We adopt the fiction that each good is demanded on its own as if it were a final good. Because of the extensive possibilities for regional substitution of intermediate goods, this approximation should be quite acceptable. That is, depending on which regional intermediate good is used in producing a final good, there should be a variety of prices and qualities in the market place which may be chosen by the consumer as if he were buying the intermediate good himself.

First, let us examine the determinants of export demand. In general, the total demand for a product depends upon total income and upon relative prices. When prices change, the mix of the consumption bundle shifts in accord with the income and substitution effects. In a regional context, goods are also identified by region. Thus if many regions produce the same good, the substitution effect is very large and a small increase in regional price will lead to a large decrease in regional demand, even though the total demand for the type of good is virtually unchanged. Thus the specification of the demand for exports as a function of the national output of the product and the Boston delivered price relative to that elsewhere, captures the very important regional substitution effect. Furthermore, the transportation cost from Boston to the national markets enters directly as a component of

the Boston price.

The second component of demand is local demand. Since residents satisfy only a portion of their demand for a product from local producers, a rise in Boston's relative price or a fall in transport costs should result in a substitution in favor of local firms. The major determinant of local demand is still of course, local income.

The supply equations are based upon standard micro-economic theory. The supply of industry output in the short run depends only upon the technology and cost of the variable factors of production relative to the output price. However, the location of the supply curve depends upon the stock of the fixed factor. Thus the supply of industry output should be a function of the cost of labor, the stock of capital, the price of output, and technology. If a specific production technology such as the Cobb-Douglas or Constant Elasticity of Substitution (CES) is assumed, a specific functional form is implied. This approach requires measurement of the stock of capital for each industry and it is well known that the assumptions required for an exact measure are unrealistic. However, approximate measures based upon either the perpetual inventory model or the vintage model can be constructed upon plausible assumptions. The use of the vintage model provides a simple way to correct for differences in the efficiency of the capital used, as for example when it is relatively obsolete as we argued must be the case in Boston. Furthermore, observation of the efficiency of investment in other parts of the United States may lead to a more informed set of assumptions.

The supply of output may also depend on the availability of land since land or space can be considered as another factor of production. Casual observation of the shifts in labor-land ratios as plants move from central city locations to suburban sites indicates that there is substantial room for substitution between these factors. Without time series data on land use, we must adopt the fiction that space is a variable factor of production. This can be partially justified for annual data by observing taht short run changes in the space input can be achieved by provision of parking facilities, rental of warehouse space, shifts of personnel away from space intensive sites, or differing technologies in construction or demolition of minor plant additions. Thus a rise in land rental rates should decrease the space input and, thereby, the quantity of output supplied.

The output is determined therefore, by both demand and supply equations. Specifically, the local income, New England income, national output and price, transportation costs, labor costs, land rentals, and stock of capital measured on an efficiency basis are the variables which jointly determine the output and price of each industrial component.

For a typical sector the export demand, local demand, and supply equations have the following forms:

(1) $Q^{ED} = Q^{ED}(p/p^{US}, Q^{US}, Y^{\text{New England}}, T)$

(2) $Q^{LD} = Q^{LD}(p/p^{US}, Y, T)$

(3) $Q^{S} = Q^{S}(p, w, r, K, t)$

(4) $Q^{S} = Q^{LD} + Q^{ED}$

where p is the Boston price of the industry output, Q is real value added, Y is disposable income, T is transportation cost, w is the labor

cost to the industry, r is the rental cost of land, K is the capital stock, and t is an index of technology. For years in which exports and local demand cannot be separated, only the sum of (1) plus (2) can be estimated. Solving these equations for Q we obtain a reduced form which indicates that output depends on incomes, wages, rentals, capital stock, technology, U.S. prices and transportation costs. For specific sectors various modifications are required.

Employment.

The demand for labor is a derived demand for employment in each of the industrial sectors. Profit maximizing firms will seek to hire workers until their marginal product equals their wage, assuming there are many firms in the industry. However, the actual cost to different industries of the labor they hire is not the same since the labor force is not homogeneous. The occupational mix of different industries varies widely as does the average wage paid by each industry. Assuming that the occupational mix of the labor force employed by an industry is technologically fixed over the period studied, the expansion of employment in that industry will require the hiring of a mixture of occupations which each command a different wage. Thus one industry may find that the wage for an additional "mixed" worker is substantially higher than another. Taking the relative occupational wages as fixed or changing slowly in response to differential rates of supply of occupational workers, the wage of the "mixed" worker can be written as proportional to a basic wage such as manufacturing production workers. The labor demand functions are determined by setting the marginal revenue product equal to this "mixed" worker wage. For either a Cobb-Douglas or a CES technology, these equations are very simple.

The typical labor demand function for an industry will be of the

form:

(5) $E = E(Q, w/p)$

where E is employment Q. is output, and w/p is the real labor cost to that industry. The equation could be written in terms of the fixed factors and output; however, by rewriting the equation in terms of output and wages we obtain a very simple form which does not require either capital stock or technological variables.

Prices and Wages.

The overall wage level in Boston including the individual occupational wages must respond to conditions of excess demand. When the labor market is very tight, the rate of increase of wages would be expected to be high. Expected rates of change of prices may lead to further wage rises. The traditional measure of labor market tightness is the level of unemployment. Some more recent studies have suggested that the average duration of unemployment may be an even better measure of the tightness of the market since the level of unemployment reflects voluntary labor turnover and can give misleading results because such turnover may actually be higher in good times than in bad. Furthermore, recent shifts in the composition of the labor force may lead to an apparent shift in the response of wages to unemployment rate. Careful adjustment of the unemployment rate to correct for these factors should lead to a pronounced effect of excess aggregate demand.

The determination of the level of prices in a city is very closely linked with wage determination. The three major components of the consumer price index are the prices of commodities, services, and housing. It is clear that each is largely determined by a different mechanism. Most commodities are imported and therefore the price will be the same as the national price except for the cost of transportation.

The service sector is so very labor intensive that a rise in the cost of labor is translated directly into an increase in the price of services. The cost of housing depends primarily on the rental rate for space and housing construction costs. The rental rate for land is explicitly modeled in the location model but an approximate relation can be established at the macro level. As income and population rise, there is increasing demand for land with successively decreasing degrees of accessibility to the central city. Assuming no shift in taste patterns, this should bid up the price of land everywhere within the external margin and thus its rental rate. The equilibrium rental rate may however be affected, by the price of substitute commodities.

A set of equations for this portion of the model is as follows:

$$(6)\quad \dot{w}/w = \dot{w}/w(U,\ \dot{p}^e/p^e)$$

$$(7)\quad p = p(p_c,\ p_s,\ p_h)$$

$$(8)\quad p_c = p_c(p_c^{US},\ T)$$

$$(9)\quad p_s = p_s(w)$$

$$(10)\quad p_h = p_h(r,C)$$

$$(11)\quad r = r(Y,p_c)$$

where $\dot{w}/w$ is the rate of change of wages in the city taken as production worker wages in manufacturing. U is the unemployment rate, p^e is the expected price level; p_c, p_s, p_h are the prices of commodities, services and housing which make up the consumer price index p, C is an index of construction costs, and r is the rental rate for land.

Distribution of Income.

The number of jobs at different occupational skill levels is estimated in the employment sector of the model. In so far as relative occupational wages are constant over time, this implies a distribution of wage income. This however, misses the variance of wages within occupations, and in order to obtain a sensible approximation to the distribution of wage income, this variance must be included. Moreover, occupational wage differentials themselves vary over time in response to relative shortages in different occupations. Thus the wage relatives also shift in response to labor supply and perhaps to job training programs in particular. Further problems in the estimation of household income distribution are the distribution of non-labor income, household formation and labor force participation rates, especially of secondary workers. Since scant data are available on these matters, Census information must be used to describe a plausible transformation of the wage distribution into household income distribution. This section of the model is necessarily more mechanical than others but maintains its focus on the wage distribution as the primary factor affecting the income distribution.

Migration of Capital.

In the short run the capital stock in an industry is assumed to be fixed; but in the long run capital can enter the region as new

investment or it can leave through depreciation and conversion. Two types of investment behavior should probably be considered. Local investors who have successful enterprises may choose to expand when conditions are right. Probably more important are the national investors who search for the location in which a particular investment would yield the highest rate of return. These criteria would often lead to the same observable behavior especially with regard to large investments.

The first pattern suggests either the standard flexible accelerator model or an expected profit model. The second requires comparison with non-Boston data to determine Boston investment. If the investor is to compare the expected yield in various locations, the model builder must similarly compare relevant observations of yield. Thus the rate of return to capital for a given industry can be calculated for a series of alternative locations in the nation, including the primary rivals. The rate of return in Boston relative to that in the most attractive alternative site is hypothesized to be the prime determinant of the share of national new investment in each particular industry which is placed in Boston. Over the sample period the most attractive alternative city for each industry should be allowed to change to reflect changing regional factors.

The measurement of the rate of return to capital is the keystone to this approach. Since it should be measured net of labor costs, taxes, land rentals and transportation costs, policies which alter these "prices" within Boston will have an effect upon new investment. Furthermore, agglomoration economies should lead to a decrease in costs depending on the size, density or diversity of the city in question.

A typical investment equation for an industry would be:

$$(12) \quad I^L/I^{US} = I(R^L, R^A, D)$$

where R is the rate of return to capital, L means local, A stands for the most profitable SMSA in the country for this industry excluding Boston, and D is an index of diversity and density designed to capture agglomoration economies. The relation is assumed to adjust only slowly so a rather long lag distribution must be allowed.

Labor Migration.

In the long run, labor also will migrate to achieve more favorable circumstances. Specific objectives are high real wages and low unemployment or perhaps high expected wages which is the product of unemployment and the employment rate. Low costs of living, in particular, inexpensive housing, will be reflected in a higher real wage for a given money wage. The level of welfare payments or other governmental transfers might also possibly influence migrant decisions. These variables all measure pulling influences, yet often the push is also important. The rural-urban shift and the South-North flow, while nearly exhausted, explain much of past migration patterns.

The migration equation could take the following simple form:

$$(13) \quad NM = NM(U, w/p, U^{US}, (w/p)^{US})$$

where NM is net migration into Boston. Again, a lengthy distributed lag is assumed.

VI. Conclusion and Summary

In this paper we have formulated an econometric model of a metropolitan area designed specifically for policy purposes. For a model to be useful for policy purposes it must not only be a reliable estimate of the appropriate behavioral relations but must include channels through which policys can act. Most existing metropolitan or regional models are completely inadequate for this task. Partly, this is because policy tools are not built into the models, but more important, these models have been designed for forecasting and therefore have paid less attention to the specification of the behavioral relations. Generally, existing models have emphasized either the demand for output or the supply of output as the primary determinant of metropolitan production. Joint determination of quantity and price has been a keystone of economic theory since Marshall and in this case we feel that it is an essential element of a model which seeks a structural explanation for the growth of a metropolitan region. Our model of the Boston SMSA is formulated so that output in each of the manufacturing and non-manufacturing sectors is jointly determined by supply and demand for the product. Labor demand is a derived demand obtained by setting marginal revenue product equal to the wage. Labor supply is incorporated through adjustments in the wage rate which responds to unemployment. In the long run, the mobile factors of production, labor and capital, are allowed to migrate in or out of the metropolitan area seeking desirable places to live and produce.

Although the model is more complicated than some existing models,

it is far simpler than the large metropolitan projection models of the 50's and early 60's. We feel that the difficulties in constructing this model will be more than repaid by its usefulness in policy formulation and by its contribution to our understanding of metropolitan growth and development.

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